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1.	Your reference	SJC/P01904UK
2.	Patent application number *(The Patent Office will fill in this part)*	0222680.1 — 01 OCT 2002
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Haswell Moulding Technologies Limited Unit 3, Rice Bridge Industrial Estate Thorpe Le Soken Essex CO16 0HH
	Patents ADP number *(if you know it)*	8474421001
	If the applicant is a corporate body, give the country/state of its incorporation	UK
4.	Title of the invention	Power Generator
5.	Name of your agent *(if you have one)*	~~Lewis & Taylor~~ — MARKS & CLERK
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	~~144 New Walk Leicester LE1 7JA~~ — 144 New Walk LEICESTER LE1 7JA
	Patents ADP number *(if you know it)*	~~711002~~ — ADP No. 8691164001
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or each of these earlier applications and *(if you know it)* the or each application number	Country / Priority application number *(if you know it)* / Date of filing *(day / month / year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and filing date of the earlier application	Number of earlier application / Date of filing *(day / month / year)*
8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'yes' if: a) any applicant named in part 3 is not an inventor, or b) there is an inventor who is not named as an applicant, or c) any named applicant is a corporate body.*	Yes

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	Description	14
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	Priority documents	
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	Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
	Request for preliminary examination and search *(Patents Form 9/77)*	One
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11. I/We request the grant of a patent on the basis of this application.

Signature Lewis & Taylor

Date 26 September 2002

12.	Name and daytime telephone number of person to contact in the United Kingdom	CHURCH, Simon John (0116) 233 8181

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TITLE: Power generator

The present invention relates to a power generator, more particularly, but not exclusively, to a power generator for supplying power to a remote telemetry apparatus for transmitting data from a rotatable body. The invention is particularly suitable for use with an in-wheel tyre monitoring apparatus for a vehicle. The invention also relates to a power consumption protocol, more particularly, but not exclusively, to a low power consumption protocol for controlling the consumption of power from a power generator for supplying power to a remote telemetry apparatus for transmitting data from a rotatable body.

A tyre monitoring apparatus for a vehicle measures principally the pressure within the tyres of a vehicle. Such a tyre monitoring apparatus may also measure other parameters within a tyre environment, for example the local temperature of a tyre. The measured data is then transmitted, via a radio wave link to the cabin of the vehicle, for example, where it is electronically processed before being displayed to the driver of the vehicle. The recipient of the transmitted data is then able to monitor any changes in the condition of the tyre, for example to avoid damaging the tyre(s) of a vehicle. This has particular advantage at high vehicle speeds, when the environment within the tyre is at its most hostile and the likelihood of damage to the tyre is at its greatest.

The majority of existing tyre monitoring apparatus use a battery as the power source for the parameter sensors and associated electronics located on or within the wheels or tyres. Such arrangements have several undesirable limitations, for example limited battery life or the size and weight of equipment which can be accommodated within a vehicle wheel or tyre. In particular, if there is a limited power source available, as a result of weight implications for example, the number of data transmissions that can be relayed for processing is compromised.

It is an object of the invention to reduce or substantially obviate the disadvantages referred to above.

According to a first aspect of the present invention, there is provided a power generator which comprises a piezoelectric element, an actuating mass and control circuitry, in which the actuating mass is adapted to deflect the piezoelectric element in response to external forces acting on the mass to generate an electrical charge, characterised in that the control circuitry forms at least part of the actuating mass.

Preferably, the control circuitry is encased in a potting compound which also contributes to the actuating mass.

Preferably, the power generator includes a housing adapted to be mounted to a rotatable body, for generating cyclic pulses of charge from the piezoelectric element.

In a preferred embodiment, the control circuitry includes sensor circuitry for monitoring environment parameters local to the housing.

According to a second aspect of the invention, there is provided a telemetry unit for mounting to a rotatable body, the telemetry unit comprising control means, sensor means for monitoring the environment local to the telemetry unit, and transmission means for transmitting data from the sensor circuitry to a remote location, the unit further comprising a piezoelectric power generator adapted to generate and store an electrical charge in response to rotation of the body for powering the unit, characterised in that the control means is arranged to vary the rate of transmission of data from the telemetry unit in dependance on the rotary speed of the rotatable body.

Preferably, the piezoelectric power generator is arranged to produce at least one pulse of electric charge for each rotation of the body, and the control means is adapted to monitor the number and/or frequency of the pulses generated in order to determine the appropriate rate of transmission of data.

Preferably, the control means is adapted to initiate sensing of the environment and transmission of the sensed data after a predetermined number of pulses has been detected.

According to a third aspect of the invention, there is provided a method for selectively controlling the power consumption of a telemetry unit having a power source, characterised in that the method incorporates a power consumption protocol including the successive steps of: initiating power to a data measurement circuit for measuring data from the environment local to the power source; disabling power to the data measurement circuit; initiating power to a data transmission circuit; transmitting data from the measurement circuit; and disabling power to the transmission circuit.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is an exploded perspective view of an in-wheel power/sensor unit for use in a preferred embodiment of the invention;

Figure 2 is a partially cross-sectional view of the in-wheel power/sensor unit shown in Figure 1 in an assembled, rest position;

Figure 3 is a perspective view the in-wheel power/sensor unit shown in Figure 2;

Figure 4 is a schematic plan view of the piezoelectric disc and brass mounting which forms part of the in-wheel power/sensor unit shown in Figures 1 to 3; and

Figure 5 is a flow diagram showing the stages involved in a low power consumption protocol according to a preferred embodiment of the invention.

Referring to Figures 1 to 4, an in-wheel power generator/sensor unit forming part of an in-wheel tyre monitoring apparatus is indicated generally at 10. The unit 10 includes a housing 12 containing a piezoelectric element 11 for generating electrical power to operate the circuits of the unit 10. The housing 12 is made as a reinforced injection moulding composite to withstand the harsh environment within a vehicle tyre. The piezoelectric element 11 is in the form of a piezoceramic disc 14 having a radius R which is mounted centrally on a brass

disc 15 having a larger radius.

The housing 12 has a base 16 having a shallow convex outer profile, indicated at C in Figure 2, for bonding to a correspondingly arcuate interior surface of a vehicle tyre. The base 16 defines a chamber, indicated at 18 in Figure 1, having an internal base wall 20. The base 16 includes recesses 22, one of which can be seen clearly in Figure 1, on which a part of the periphery of the brass disc 15 is supported, so that the central portion of the brass disc 15 is spaced apart from the base wall 20. A cover 26 is received on the base 16, which overlays the part of the periphery of the brass disc 15 supported on the recesses 22, such that the disc is clamped between the cover 26 and the recesses 22 along two edge portions 47.

A cap 28 is provided over the cover 26, which includes a central formation 30 which extends through a central aperture 27 in the cover 26.

A printed circuit board (PCB) 32 is mounted in the housing 12 on the cap 28. The PCB 32 includes a micro processor, a radio frequency (RF) transmitter, pressure and temperature sensor circuitry and super-vision and control circuitry, all of which are not illustrated and which form part of the in-wheel tyre monitoring apparatus, as will be described below. The PCB 32 also includes a rectifier for converting an alternating current output from the piezoceramic disc 14 into a direct current output; an energy storage element in the form of a capacitor, which stores the direct current output from the rectifier until required, and a DC-DC controller which is provided for regulating the voltage output from the capacitor. The PCB 32 is in electrical communication with the piezoceramic disc 14 via two wires, not shown. The PCB 32 is securably located on the cap 28 by a potting compound 34, to protect the PCB 32, e.g. during installation or transit and from the harsh environment within a rotating vehicle wheel. The potting compound 34 can be any suitable type but in this embodiment is a two-part epoxy adhesive.

An actuator 36 is disposed between the piezoceramic disc 14, the cover 26 and the cap 28. The actuator 36 consists of an integrally formed foot 38 and a stem 40. The stem 40 extends into the central formation of the cap 28 and includes a central bore 42. As can be seen clearly

in Figure 2, the foot 38 includes an integrally formed projection or nose 44, which is in contact with the piezoceramic element. The nose 44 extends diametrically across the piezoelectric element 11, as indicated in Figure 4, which shows the contact area 45 of the nose 44 on the piezoelectric element 11 and the areas of support 47 for the disc 15 on the base 16. Hence , the piezoelectric element 11 is configured as a simply supported beam, supported on one side by the recesses 22 in the base 16 and contactable on its opposite side by the nose 44 of the actuator 36.

The actuator 36 is connected to the cap 28 by a screw 46 which passes through the cap 28 and is securably received in the bore 42 of the stem 40. The base 16 is connected to the cover 26 by four screws 48, which pass through the corners of the base 16 and which are securably received in the cover 26.

The arrangement is such that the piezoelectric element 11 can be deflected downwardly (as viewed in Figure 2) under the influence of the actuator 36, as will be described in more detail below. However, the maximum deflection of the piezoelectric element 11 is limited by the distance between the underside of the brass disc 15 and the internal base wall 20, set at 0.4 mm in the embodiment of Figures 1 to 4. The movement of the actuator 36 within the housing 12 in the opposite direction, i.e. perpendicularly away from the piezoceramic disc 14, upwards as viewed in Figure 2, is restricted by walls 27 of the cover 26. In the embodiment of Figures 1 to 4, the maximum distance between the upper side of the foot 38 of the actuator 36 and the walls 27 of the cover 26 is 0.6 mm when the power generator 10 is in the rest position shown in Figure 2. Hence, the maximum travel of the actuator 36 within the housing 12 is 1 mm in the embodiment of Figures 1 to 4. The maximum distance of travel of the actuator 36 within the housing 12 is set at a predetermined low value to protect the piezoceramic disc 14 from damage due to deflection and/or impact of the actuator 36 on the upper surface of the piezoceramic disc 14 in use.

The arrangement of the piezoceramic disc 14 on the housing 12, in combination with the components of the PCB 32 which are associated with the piezoceramic disc 14, as described above, form part of a power generator in accordance with the invention. The power generator

provides power for the circuitry of the in-wheel tyre monitoring apparatus.

Operation of the power generator will now be described, by way of example in which the in-wheel power generator/sensor unit 10 is mounted in a tyre on the wheel of a vehicle, with the outer surface of the base 16 of the housing 12 bonded to the correspondingly arcuate profile of an interior surface of the tyre.

The piezoceramic disc 14 is of any suitable known construction. Hence, it will be appreciated that mechanical excitation of the piezoelectric disc 14 generates a voltage. The effect is substantially linear, i.e. the electric field generated varies directly with the applied mechanical stress, and is direction dependent, so that compressive and tensile stresses generate voltages of opposite polarity.

The cap 28, PCB 32, potting compound 34 and the actuator 36 act on the disc 14 as a single unit mass, in use. When the wheel is in rotation, centrifugal forces act on the cap 28, PCB 32 and the potting compound 34, which urge the actuator 36 radially outwards in the direction of the piezoelectric element 11. This centrifugal action on the actuator 36 causes the piezoelectric element 11 to deflect, typically between 0.2 to 0.4 mm at its central region 45 from a rest position when the wheel is not in rotation. Since the piezoelectric element 11 acts as a simply supported beam and the nose 44 of the actuator 36 is in contact with the disc 14 at the central position 45 between the area of support for the brass disc 15, the deflection is in the form of a uniform bending of the discs 14 and 15 between the two areas of support 47 of the brass disc 15.

As will be appreciated, as the vehicle is in motion, with every revolution of the wheel, the external area of the tyre adjacent the in-wheel power generator/sensor unit 10 comes in to contact with, and is deformed by, the surface along which the vehicle is travelling. This deformation is transmitted to the power generator, ultimately in the form of a deformation of the piezoelectric element 11. Hence, the piezoceramic disc 14 is subjected to variations in mechanical excitation during rotation of the wheel on the road surface, whereby each excitation results in a potential difference being generated by the piezoceramic disc 14. This

process is set out below, with reference to a rotating wheel, starting from a position where the area of the tyre adjacent the in-wheel power generator/sensor unit 10 is moving towards contact with a road surface.

With the wheel in rotation, the actuator 36 is in contact with the piezoceramic disc 14, under centrifugal action from the cap 28, PCB 32 and potting compound 34, as described above. The piezoceramic disc 14 therefore experiences a substantially constant deflection under the centrifugal forces which are transmitted through the actuator 36. As the wheel rotates further, the area of the tyre adjacent the in-wheel power generator/sensor unit 10 comes into contact with the road surface and deforms. This deformation results in a deceleration of the tyre in the region of the point of contact with the road surface, causing a sudden reduction in the centrifugal forces experienced by the actuator 36, almost instantaneously, substantially to zero. This change in centrifugal acceleration causes a reduction in the deflection experienced by the piezoceramic disc 14 under action of the actuator 36 and generates a first pulse of electrical charge, which is communicated to the PCB 32.

As the wheel rotates further, at the instant where the area of the tyre adjacent the unit 10 moves away from contact with the road surface, the acceleration of the tyre adjacent the unit 10 increases suddenly, which results in an instantaneous increase in the centrifugal forces experienced by the actuator 36. Hence, piezoceramic disc 14 is again caused to deflect under centrifugal action of the actuator 36, cap 28, PCB 32 and potting compound 34, as described above, which generates a second pulse of electrical charge of opposite polarity to the first pulse described above, which is communicated to the PCB 32.

Hence, during a single revolution of the wheel two pulses of electrical charge, of opposite polarity, are generated in quick succession, constituting a single alternating current output. The rectifier rectifies the alternating current output into a direct current output, which is stored in the capacitor for use to power the in-wheel tyre monitoring apparatus. For each revolution of the wheel, a small storable electrical charge is generated, typically of 5-10 nano coulombs.

In addition to the storable charge generated with each revolution of the wheel due to contact with the road surface, the power generator/sensor unit 10 may also transmit other excitation forces to the piezoelectric element 14, for example accelerations/deflections which are caused by vibrations due to imperfections in the road surface, or out of balance forces on the wheel itself. If the excitation is sufficient to cause deflection of the piezoelectric disc 14, an additional storable charge will be generated and stored in the capacitor, as described above.

The in-wheel power generator/sensor unit 10 is particularly advantageous in that the control circuitry is used as an actuating mass for the piezoelectric element 11. In the described embodiment, the weight of the cap 28, the PCB 32 and the potting compound 34 operate as a single unit to act as an actuating mass/exciter for the piezoceramic disc 14, without the need for any additional mass. Hence there is an overall saving in weight in the power generator, to minimise localised wear caused by the in-wheel power generator/sensor unit 10 adjacent the area of mounting in the vehicle tyre, to reduce the appearance of a localised bald spot in the tread of the tyre, for example.

The outer surface C of the base 16 may include an external profile for complimentary engagement with the internal pattern of a vehicle tyre, to limit further the effects of localised wear on the tyre, in use.

In order to utilise the small amounts of power generated by the power generator and to remove the need for a battery backup to power the in-wheel tyre monitoring apparatus, an ultra low power consumption protocol is used to control the consumption of power stored by the capacitor.

Operation of a preferred embodiment of an in-wheel tyre monitoring apparatus will now be described by way of example, illustrating the stages which are implemented to ensure that the optimum low power protocol is realised, starting with the monitoring apparatus in a 'sleep' mode, with reference to Figure 5. As referred to above, the in-wheel tyre monitoring apparatus includes a in-wheel power generator/sensor unit 10 having a piezoelectric power generator, a micro processor, a radio frequency (RF) transmitter, pressure and temperature

sensor circuitry and supervision and control circuitry.

Example 1

Stage 1

The micro processor is in 'sleep' mode, in which all internal processing is suspended, apart from a monitor circuit, for monitoring the 'wake up' requirements of the micro processor. In this embodiment, the monitor circuit monitors an externally referenced clock in the form of a crystal oscillator, located outside the micro processor in the in-wheel power/sensor unit. Hence, in sleep mode, the majority of the micro processor circuitry is disabled and the power consumption of the in-wheel tyre monitoring apparatus is at a minimum level, for example approximately 24 micro ampere of supply current.

Stage 2

After a predetermined time, in this embodiment 60 seconds, the monitor circuit 'wakes up' the micro processor. Upon 'wake up', the micro processor switches from the external clock to an internal clock, in the form of an internal resistor capacitor oscillator. This switch is implemented to facilitate a higher speed operation of the analogue to digital conversions and subsequent calculations which are utilised by the tyre monitoring apparatus. The switch also initiates power to the internal circuitry of the micro processor, which allows the main program of the micro processor to be used and to enable the micro processor to enter a measure and control phase.

Stage 3

Once the micro processor has 'woken up', power is provided to the temperature and pressure sensor circuitry. A prescribed time is then allowed to elapse, in this embodiment 14 milli seconds, to facilitate settling of the sensor circuitry, after which time the micro processor measures the local pressure and temperature within the tyre. The values are then stored

within the micro processor and the power to the sensor circuitry is removed instantaneously.

Stage 4

The stored pressure and temperature values are concatenated with a sensor identification and cyclic redundancy check to form a data packet for transmitting to a receiver unit/display unit in the vehicle.

Stage 5

The micro processor then switches from the internal clock back to the external clock. This change is employed to ensure accurate time signals for the transmission of the data via the radio frequency (RF) link, since the external clock is a quartz crystal time reference unit, which ensures that a higher absolute frequency accuracy is attainable than with the internal clock.

Stage 6

The micro processor sets a control line to a logic high of 3v, which enables the RF transmitter, thus causing it to emit a radio frequency carrier. A settling time of 1 milli second then elapses to facilitate settling of the RF transmitter components prior to the transmission of data from the PCB 32. A pseudo bit pattern, used to bias a radio frequency data slicer, is then concatenated with the sensor identification and cyclic redundancy check for transmitting. The data to be transmitted is then frequency modulated onto a 433MHz radio wave for propagation to the receiver unit.

Stage 7

The data is transmitted and power to the RF transmitter is inhibited instantaneously, at which point the micro processor then enters 'sleep mode'.

Hence, by utilising the low power protocol described in stages 1-7 of the above example, the in-wheel tyre monitoring apparatus utilises only a small amount of power from the power generator, to transmit a reading of the local pressure and temperature within the tyre. After use, the micro processor remains in sleep mode for a predetermined period, as referred to in Stage 2 above, while the energy stored in the capacitor is recharged by excitation of the piezoceramic disc 14, as described with reference to Figures 1 to 4. Hence, using a continuous cycle of stages 1-7, the in-wheel tyre monitoring apparatus is able to monitor the local condition of the tyre, utilising the small electrical charges generated by the piezoceramic disc 14, without the need for a back-up battery supply.

The data transmitted to the in-car receiver unit is shown to the driver of the vehicle on the display unit for the or each of the sensor circuits in the tyre monitoring apparatus, with respect to each tyre of the vehicle. The display unit informs the driver of the data visually and/or by audible means, for example a link to the audio system in the vehicle.

Each tyre/wheel of the vehicle is marked by an individual identifying feature that relates to a specific sensor located within that tyre. This identifying feature is also represented on the display unit, in combination with the data from the sensor within the tyre. In the event that the wheel is moved to another position on the vehicle it can always be related to the relevant information on the display unit. Suitable identifying features include colour-coded symbols and alpha numeric symbols.

Each in-wheel sensor has a unique electronic serial number, which can be used to aid the security of the radio transmission data. The unique electronic serial number can also act as an electronic tagging feature for security and anti counterfeiting purposes.

With reference to the preferred embodiment of the power generator, it has been described that a storable electrical charge is generated by the piezoelectric element with each revolution of the vehicle wheel. Therefore, it will be appreciated that the generation of charge is proportional to the speed at which the vehicle is travelling. In the above example of the power consumption protocol, the time delay between transmission of data from the tyre

monitoring apparatus and the "wake up" of the micro processor for measuring and transmitting a further reading is set to a predetermined value. In a slow moving vehicle, the electrical charge which is generated and stored within a predetermined time period is less than would be generated and stored in a vehicle travelling at a faster speed in the same time period. Therefore, the time interval between "wake up" of the microprocessor is set at a predetermined value, selected to allow a sufficient electrical charge to be generated and stored for measurement and transmission of the parameters of a tyre on a slow moving vehicle, for example 25 kmh.

However, as the speed of the vehicle increases, the rate of electrical charge generation also increases. Thus, the time period required to generate sufficient electrical charge to enable the tyre monitoring system to measure and transmit the tyre parameters is reduced.

To take advantage of this, the low power protocol described above can be modified so that the micro processor is "awoken" from its sleep mode at intervals relative to a function of the speed of the vehicle or the state of the electrical charge stored in the capacitor, which enables the transmission of data to be varied in proportion to the speed of the vehicle.

The following example shows a preferred mode of the invention, in which the rate of transmission of data from the in-wheel tyre monitoring apparatus is proportional to the speed of the vehicle, starting with the monitoring system in a "sleep" mode, substantially as described in example 1.

Example 2

Stage 1

As the wheel rotates, storable power outputs are produced by the power generator, one per revolution, as described above. In this embodiment of the invention, this characteristic of the power generator is used to monitor the speed of the vehicle and/or the state of charge of the capacitor. A small portion of each storable power output is signal conditioned to take in

to consideration false triggers of power which may be experienced by the piezoelectric disc 14 during rotation of the wheel, for example accelerations/deflections which are caused by vibrations due to imperfections in the road surface. The conditioned signal is then supplied to an interrupt circuit in the micro processor, which momentarily wakes the micro processor from its sleep mode and increments a counter in the micro processor. The micro processor then returns instantly to the sleep mode.

Stage 2

Both the average charge generated per revolution of the wheel and the value of stored charge sufficient to measure and transmit data from the power generator/sensor unit 10 are known. Hence, the number of "interrupts" or increments of the counter required for the capacitor to store a charge sufficient for measurement and transmission of data from the apparatus can be calculated. Therefore, the micro processor can be set to "wake up", substantially as described in stage 2 of example 1, after a predetermined number of revolutions of the wheel, for example 50 revolutions. At this point, power is initiated to the internal circuitry of the micro processor, which allows the main program of the micro processor to be used and to enable the micro processor to enter a measure and control phase.

The internal clock of the micro processor monitors the time taken for the predetermined number of revolutions to be completed. Hence, a value of average speed of the vehicle during the time period can be calculated from the elapsed time and the distance travelled which is cross-referenced from a table of data relating to the diameter of the wheel.

Stage 3

As described in example 1, once the micro processor has 'woken up', power is provided to the temperature and pressure sensor circuitry. A prescribed time is then allowed to elapse, for example 500 micro seconds, to facilitate settling of the sensor circuitry, after which time the micro processor measures the local pressure and temperature within the tyre. The values are then stored within the micro processor and the power to the sensor circuitry is removed

instantaneously.

Stage 4

The stored pressure and temperature values are concatenated with a sensor identification and cyclic redundancy check, as described in stage 4 of example 1, and the value of speed calculated during stage 2.

Further stages 5 to 7 are then carried out substantially as described with reference to stages 5 to 7 in the above example.

Since the speed of the data transmissions is proportional to the speed of the vehicle, this embodiment of the invention has a major safety improvement over known tyre monitoring apparatus, in that the information is transmitted and updated regularly, depending on the speed of the vehicle. This has particular advantage in that a catastrophic failure of a tyre is more likely to occur, possibly with greater consequences, at high vehicle speed and the system according to the preferred embodiment of the invention is more regularly updated at high vehicle speeds, thereby improving vehicle safety by warning the driver of any deflation of the vehicle tyres, for example.

In addition to the use on wheels, the invention also has use on other rotating bodies. For example, the invention has application on a rotating shaft, whereby out-of-balance forces experienced by the shaft during rotation are transmitted to the piezoceramic disc, which generates a charge for transmitting data relating to the rotatable state of the shaft.

Claims

1. A power generator which comprises a piezoelectric element, an actuating mass and control circuitry, in which the actuating mass is adapted to deflect the piezoelectric element in response to external forces acting on the mass to generate an electrical charge, characterised in that the control circuitry forms at least part of the actuating mass.

2. A power generator as claimed in claim 1, wherein the control circuitry is encased in a potting compound which also contributes to the actuating mass.

3. A power generator as claimed in claim 1 or claim 2, wherein the power generator includes a housing adapted to be mounted to a rotatable body, for generating cyclic pulses of charge from the piezoelectric element.

4. A power generator as claimed in any previous claim, wherein the power generator forms part of a telemetry unit and the control circuitry includes sensor circuitry for monitoring environment parameters local to the housing.

5. A telemetry unit for mounting to a rotatable body, the telemetry unit comprising control means, sensor means for monitoring the environment local to the telemetry unit, and transmission means for transmitting data from the sensor circuitry to a remote location, the unit further comprising a piezoelectric power generator adapted to generate and store an electrical charge in response to rotation of the body for powering the unit, characterised in that the control means is arranged to vary the rate of transmission of data from the telemetry unit in dependance on the rotary speed of the rotatable body.

6. A telemetry unit as claimed in claim 5, wherein the piezoelectric power generator is arranged to produce at least one pulse of electric charge for each rotation of the body, and the control means is adapted to monitor the number and/or frequency of the

pulses generated in order to determine the appropriate rate of transmission of data.

7. A telemetry unit as claimed in claim 6, wherein the control means is adapted to initiate sensing of the environment and transmission of the sensed data after a predetermined number of pulses has been detected.

8. A method for selectively controlling the power consumption of a telemetry unit having a power source, characterised in that the method incorporates a power consumption protocol including the successive steps of: initiating power to a data measurement circuit for measuring data from the environment local to the power source; disabling power to the data measurement circuit; initiating power to a data transmission circuit; transmitting data from the measurement circuit; and disabling power to the transmission circuit.

Claims

1. A method for selectively controlling the power consumption of a piezoelectrically powered telemetry unit, the telemetry unit forming part of a tyre monitoring system and having a piezoelectric power generator including a storage device for storing charge generated by the piezoelectric power generator, the unit further including a microprocessor, a data measurement circuit, and a data transmission circuit, in which the method incorporates a power consumption protocol for regulating the consumption of power from the piezoelectric power generator, including the successive steps of: initiating power from the piezoelectric generator to the data measurement circuit for measuring data from the environment local to the unit; disabling said power to the data measurement circuit; initiating power from the piezoelectric power generator to the data transmission circuit; transmitting the measured data; and disabling said power to the transmission circuit;

   wherein the protocol further includes a sleep mode, the length of which is varied in dependence on the amount of charge stored in the storage device, or upon the rate at which electric charge is generated by the generator.

2. A method as claimed in claim 1, in which the protocol is cyclic, so that the first protocol step of power being initiated from the piezoelectric generator to the data measurement circuit is carried out after each transmission of measured data.

3. A method as claimed in claim 1 or 2, in which the measured data is stored in the microprocessor before disabling power to the data measurement circuit.

4. A method as claimed in claim 1, 2 or 3, in which the protocol initialises power to the data measurement circuit after a predetermined time from the disabling of power to the transmission circuit.

5. A method as claimed in claim 4, in which the microprocessor monitors the time from the

disabling of power to the transmission circuit.

6. A method as claimed in claim 5, in which the microprocessor monitors the time from the disabling of power to the transmission circuit via an externally referenced clock.

7. A method as claimed in claim 6, in which the microprocessor switches from the externally referenced clock to an internal clock, after the predetermined time.

8. A method as claimed in claim 7, when dependent upon claim 5, in which the microprocessor switches to the externally referenced clock after the measured data has been stored.

9. A method as claimed in any preceding claim, in which a predetermined time is allowed to elapse between initialising power to the data measurement circuit and the measurement of data.

10. A method as claimed in any preceding claim, in which a predetermined time is allowed to elapse between initialising power to the data transmission circuit and transmission of the measured data.

Figure 1

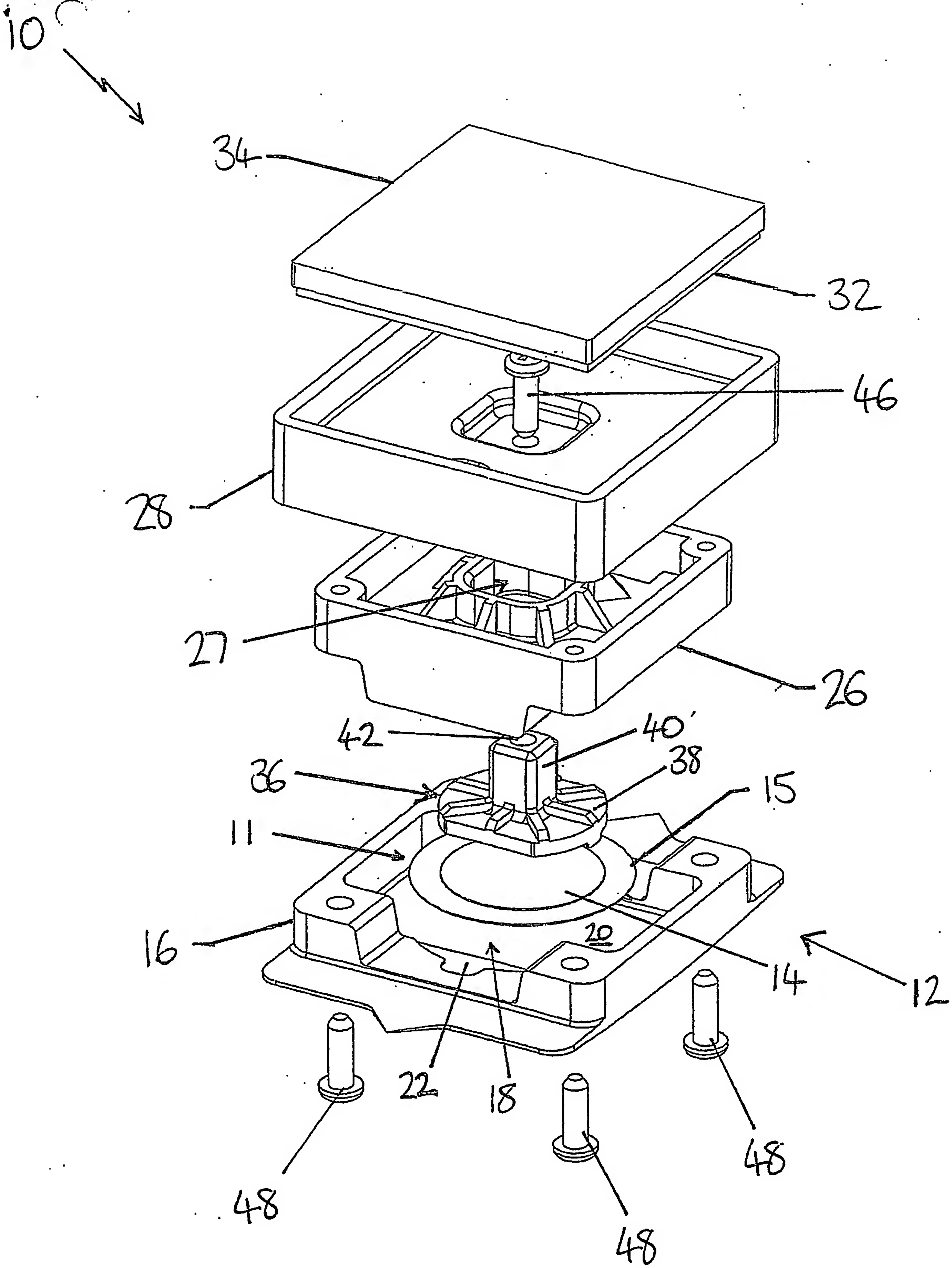


Figure 2

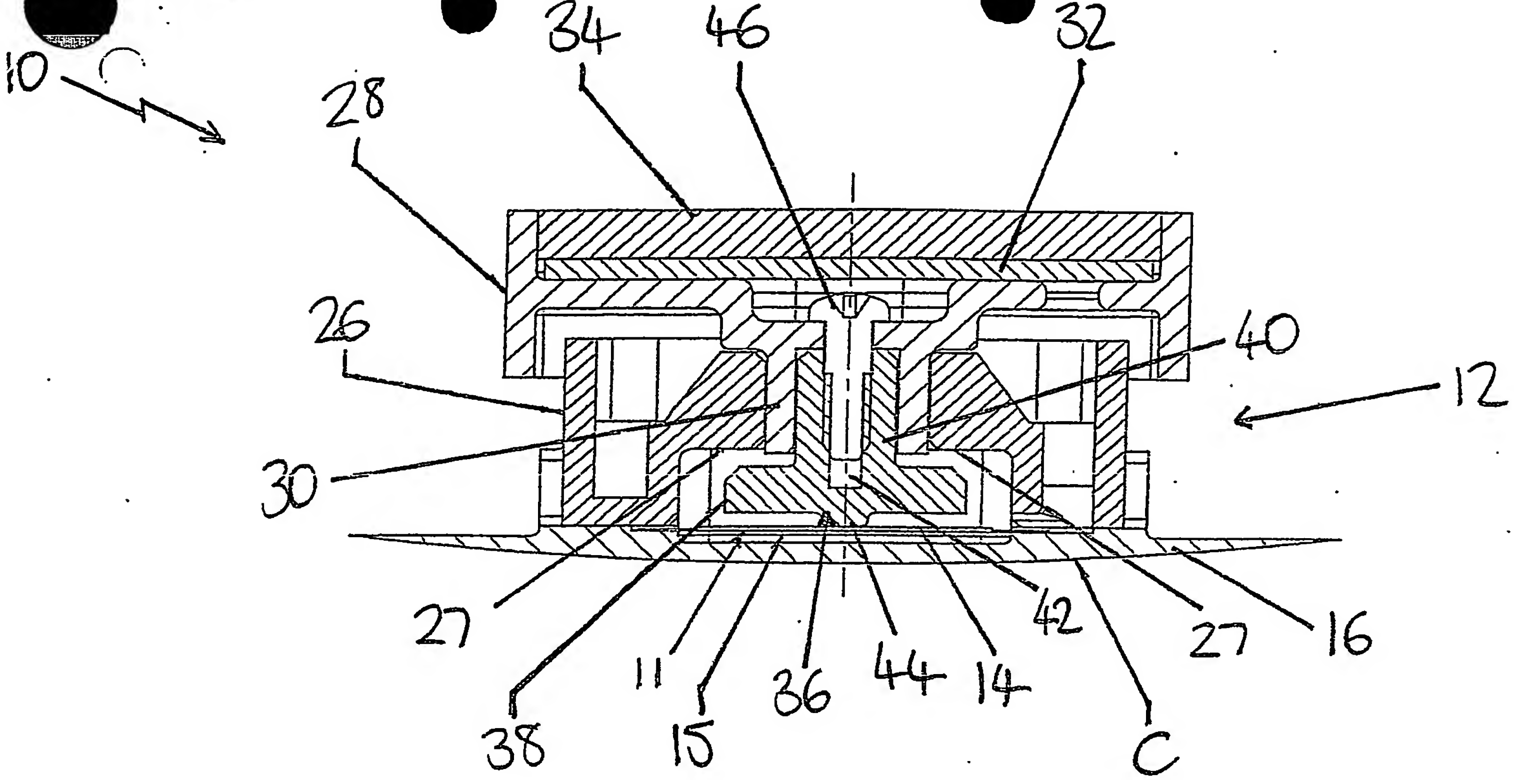


Figure 3

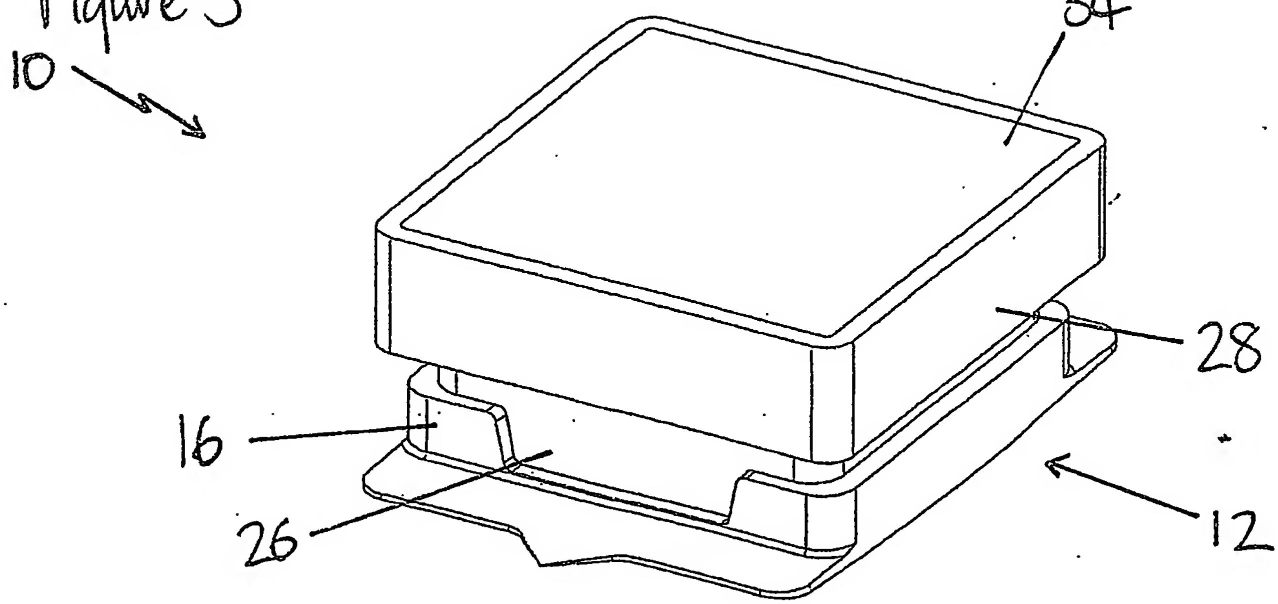


Figure 4

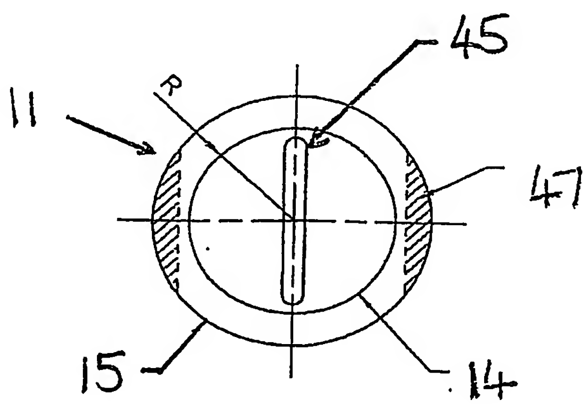
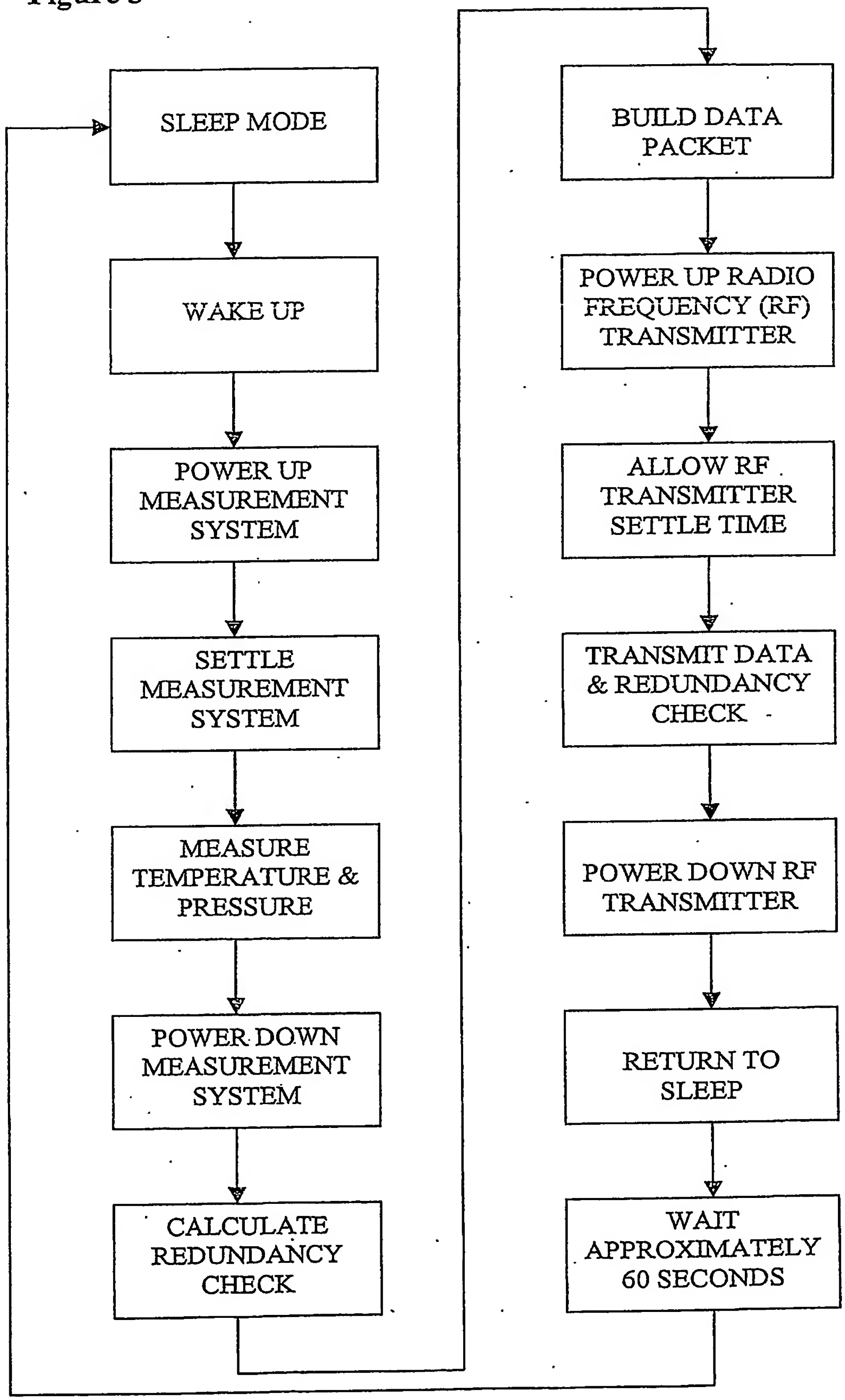


Figure 5



SLEEP MODE
WAKE UP
POWER UP MEASUREMENT SYSTEM
SETTLE MEASUREMENT SYSTEM
MEASURE TEMPERATURE & PRESSURE
POWER DOWN MEASUREMENT SYSTEM
CALCULATE REDUNDANCY CHECK
BUILD DATA PACKET
POWER UP RADIO FREQUENCY (RF) TRANSMITTER
ALLOW RF TRANSMITTER SETTLE TIME
TRANSMIT DATA & REDUNDANCY CHECK
POWER DOWN RF TRANSMITTER
RETURN TO SLEEP
WAIT APPROXIMATELY 60 SECONDS